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(56) Documents Cited

GB 2302895 A GB 2006853 A EP 0223552 A2

EP 0063519 A2 US 4298077 A

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INT CL<sup>6</sup> E21B

(54) Apparatus for circulating fluid in a borehole

(57) Apparatus (1) for circulating fluid in a borehole includes a body member (2) adapted to form a portion of a length of drillstring. The body member (2) has a throughbore (14) and a fluid port (3) extending through a side wall of the body member (2). An inner sleeve (12) is movably mounted within the body member (2) for movement between a closed position in which the inner sleeve (12) obturates the fluid port (3) and an open position in which the fluid port (3) is permitted to communicate with the throughbore (14). A pressure differential means to generate a pressure differential across the inner sleeve (12) is provided to move the sleeve (12) from the closed position to the open position in use. In addition, an indexing mechanism (7, 17) couples the inner sleeve (12) to the body member (2) to permit the inner sleeve (12) to be selectively moved between the closed position and the open position and to maintain the inner sleeve (12) in the closed or open position.

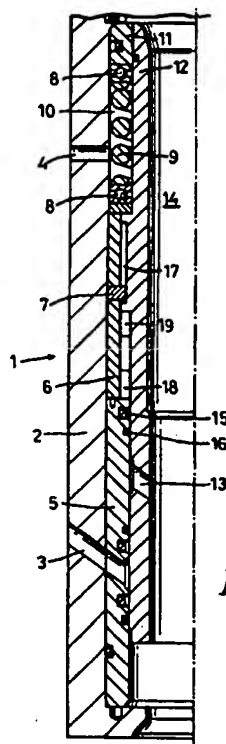
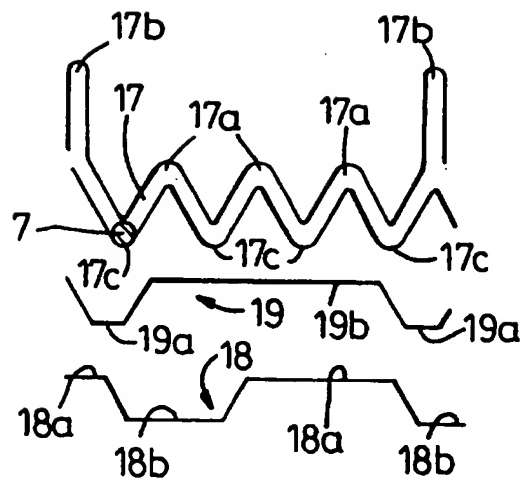
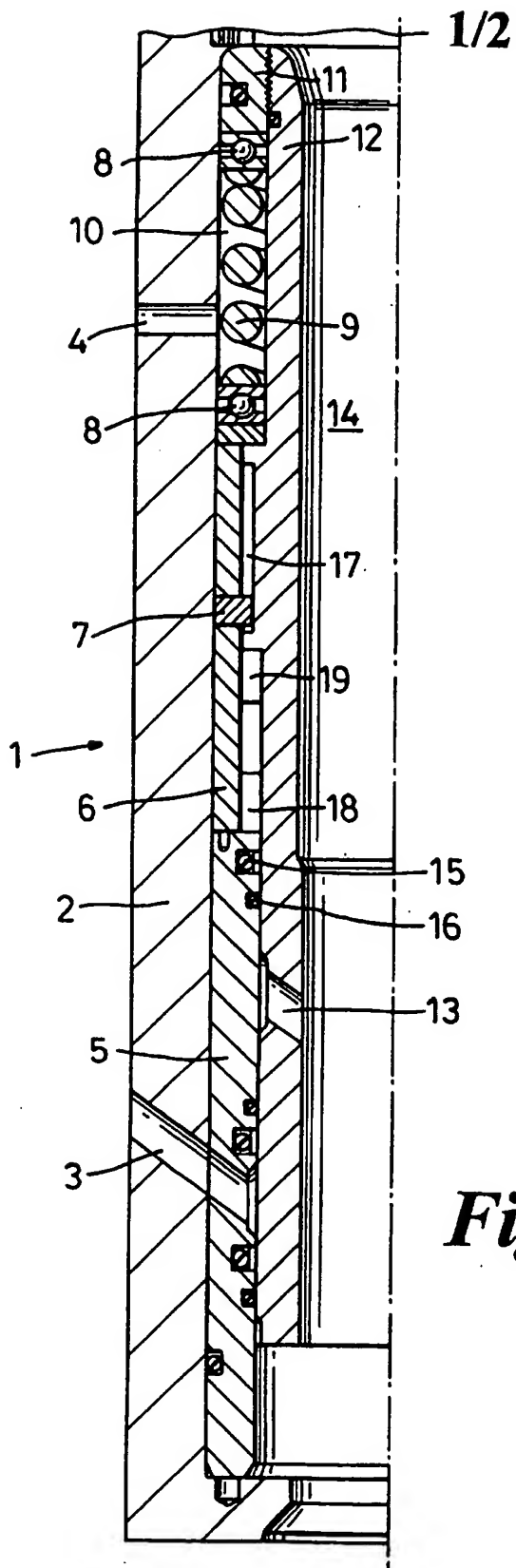


Fig. 1

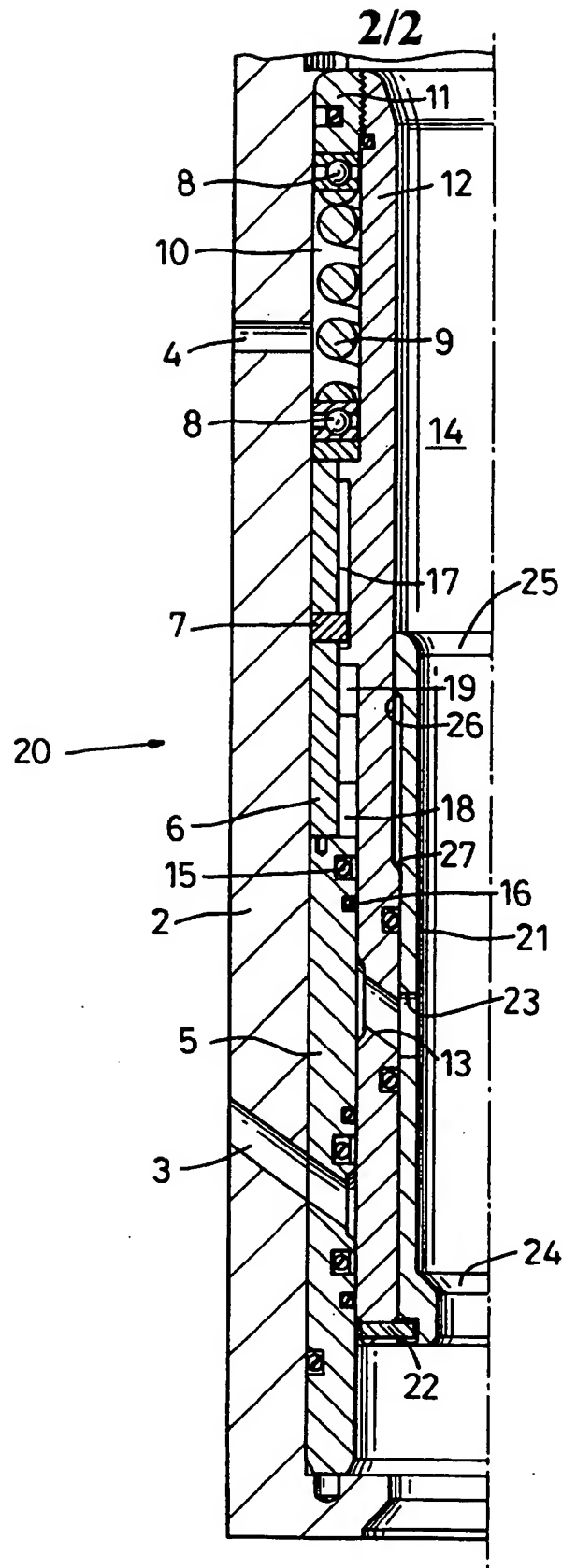
At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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**Fig. 2**

**Fig. 1**



***Fig. 3***

1    "Apparatus for Circulating Fluid in a Borehole"

2

3    The invention relates to apparatus for circulating  
4    fluid in a borehole and in particular, apparatus for  
5    incorporation into a drillstring to circulate fluid to  
6    aid removal of drill cuttings from a borehole or to  
7    control the influx of hydrocarbons into the borehole,  
8    as the borehole is being drilled.

9

10   When drilling certain types of wells, commonly extended  
11   reach, highly deviated or horizontal wells, it may be  
12   difficult to effectively remove drill cuttings from the  
13   borehole due to the well and drillpipe geometry. Drill  
14   cuttings can accumulate on the low side of the well (in  
15   deviated or horizontal wells) and create what is  
16   commonly termed a "cuttings bed". It is not uncommon  
17   for the cuttings bed to accumulate to an extent that it  
18   contacts the drillpipe. This can lead to the drillpipe  
19   becoming stuck in the well and so preventing removal of  
20   the drillstring from the borehole.

21

22   One of the ways of preventing the creation of a  
23   cuttings bed is to maintain sufficient velocity of the  
24   circulating drilling fluid or mud. If a high enough  
25   velocity of drilling fluid is generated in the annulus

1 between the drillstring and the side walls of the  
2 borehole, the cuttings will be flushed upwards out of  
3 the hole with the drilling fluid.

4  
5 However, it is difficult to maintain sufficient  
6 velocity of the drilling fluid in highly deviated and  
7 horizontal wells, especially at the locations in the  
8 borehole in which cuttings tend to accumulate. In  
9 addition, the sizing of the drillpipe, bottom hole  
10 assembly (BHA) components such as drill collars, mud  
11 motors, turbines and the drill bit, and borehole can  
12 result in a pressure drop through the system which is  
13 high enough to prevent a sufficiently high drilling  
14 fluid flow rate being maintained in the annulus between  
15 the drillpipe and the side walls of the borehole.

16  
17 One way of maintaining a sufficiently high flow rate of  
18 drilling fluid in the annulus is to incorporate a  
19 circulating sub into the drillstring which diverts  
20 fluid flow out of the drillstring and into the annulus  
21 before the fluid reaches the BHA. Alternatively, the  
22 circulating sub may be incorporated into the BHA to  
23 divert fluid from the components beneath the sub.

24  
25 One such tool has fluid flow paths running from the  
26 inside of the tool to the outside of the tool and  
27 nozzles in the flow path generate flow in the annulus.  
28 By changing nozzle size it is possible to generate  
29 different flow regimes. However, a problem with this  
30 tool is that after the nozzles have been attached to  
31 the tool and the tool is inserted into the borehole of  
32 the drillstring it is not possible to change the flow  
33 paths without removing the drillstring from the  
34 borehole. In addition, if a cuttings bed occurs below  
35 the tool, the blockage formed by the cuttings bed will  
36 tend to force more fluid out of the tool through the

1 nozzles and therefore reduce the amount of flow going  
2 through the drill bit and past the cuttings bed,  
3 thereby exacerbating the problem.

4  
5 Another known tool permits the flow path within the  
6 tool to be diverted by dropping a ball down the inside  
7 of the drillstring. The ball landing in the tool opens  
8 flow ports to permit fluid to be circulated from the  
9 inside of the tool to the annulus without passing  
10 through the drill bit. Another ball may then be  
11 dropped in order to close the flow ports. However, the  
12 tool can only function a finite number of times, after  
13 which it is necessary to remove the drillstring from  
14 the borehole in order to reset the tool. There is also  
15 the disadvantage that it is time consuming to pump the  
16 balls down the drillstring and into place in the tool.  
17 Furthermore, after one ball has been dropped into the  
18 tool it is impossible to gain access through the tool  
19 to lower sections of the drillstring using wireline run  
20 tools. The passage of the ball(s) down the inside of  
21 the drill string is sometimes problematic in highly  
22 deviated or horizontal wells.

23  
24 A further existing tool also uses a ball dropped into  
25 the drillstring and uses pumping at predetermined rates  
26 to move a piston down to expose ports in the tool to  
27 permit flow from the inside of the tool directly into  
28 the annulus of the borehole. This tool is not locked  
29 or fixed in the open or closed position and is  
30 therefore reliant on the properties of the drilling  
31 fluid (which can vary dramatically) in order to  
32 function the tool. Because of this it is not reliable  
33 in operation. In addition, the seals of the tool are  
34 prone to damage because of the way in which the tool  
35 operates and it is not proved a suitable tool in highly  
36 deviated and horizontal wells. In addition, as with

1 the tool discussed above, the balls cause a restriction  
2 preventing the use of wireline to access the  
3 drillstring below the tool. The balls also have the  
4 disadvantage that they are time consuming to pump into  
5 place.

6  
7 In accordance with the present invention, apparatus for  
8 circulating fluid in a borehole comprises a body member  
9 adapted to form a portion of a length of drillstring,  
10 the body member having a throughbore therein, and a  
11 fluid port extending through a side wall of the body  
12 member; an inner sleeve movably mounted within the body  
13 member for movement between a closed position in which  
14 the inner sleeve obturates the fluid port and an open  
15 position in which the fluid port is permitted to  
16 communicate with the throughbore; a pressure  
17 differential means to generate a pressure differential  
18 across the inner sleeve to move the sleeve from the  
19 closed to the open position in use; and, an indexing  
20 mechanism which couples the inner sleeve to the body  
21 member to permit the inner sleeve to be selectively  
22 moved between the closed position and the open position  
23 and to maintain the inner sleeve in the closed or open  
24 position.

25  
26 Preferably, the inner sleeve is in the form of a  
27 differential pressure piston and the pressure  
28 differential means may comprise sealing means to  
29 isolate a surface area of the piston exposed to  
30 pressure from outside the body member from the surface  
31 area of the piston exposed to fluid pressure in the  
32 throughbore.

33  
34 Alternatively, the pressure differential means may  
35 comprise a restriction in the throughbore to create a  
36 pressure differential within the inner sleeve so that

1 fluid flow in the throughbore generates sufficient  
2 force to move the inner sleeve from the closed position  
3 to the open position.

4  
5 Typically, the inner sleeve obturates the at least one  
6 fluid port in the closed position and a fluid port  
7 through the inner sleeve aligns with the fluid port in  
8 the body member when the inner sleeve is in the open  
9 position. Preferably, a number of fluid ports are  
10 located circumferentially around the body member and  
11 the inner sleeve.

12  
13 Preferably, the indexing mechanism may include a number  
14 of indexing positions and the inner sleeve moves to the  
15 next indexing position each time fluid flow into the  
16 throughbore is stopped and restarted. Typically, there  
17 may be a number of indexing positions in which the  
18 sleeve is in the closed position and one indexing  
19 position in which the sleeve is in the open position.

20  
21 Typically, the indexing mechanism comprises a slot or  
22 groove formed in the outside surface of the inner  
23 sleeve which co-operates with a pin mounted on the body  
24 member which engages with the slot.

25  
26 Typically, the fluid port may include a restriction to  
27 generate a pressure differential between the  
28 throughbore and the outside of the body member.  
29 Preferably, the restriction may be removable or  
30 replaceable so that different types or sizes of  
31 restriction may be inserted into the fluid port.

32  
33 The inner sleeve may move in a direction parallel to  
34 the longitudinal axis of the throughbore and rotate  
35 relative to the body member when moving from the closed  
36 position to the open position. Typically, in use, in



1 the open position the inner sleeve is closer to the  
2 drill bit than when the inner sleeve is in the closed  
3 position.

4  
5 The apparatus may also include a secondary inner sleeve  
6 which is typically movably mounted within the inner  
7 sleeve and may be moved relative to the inner sleeve to  
8 permit the fluid port to be closed in the event that it  
9 is not possible to return the inner sleeve from the  
10 open position to the closed position.

11  
12 The secondary sleeve may be operated by dropping a  
13 spherical member from the surface of the well into the  
14 throughbore which permits fluid pressure above the  
15 spherical member to move the secondary sleeve to close  
16 the fluid port and also to move to a position such that  
17 fluid may bypass the spherical member. Preferably, the  
18 spherical member is extrudable and may be plastic,  
19 elastomeric and/or a rubber material.

20  
21 Alternatively, the secondary sleeve may be inserted  
22 into the apparatus from the surface of the borehole  
23 during use of the apparatus and may include a  
24 rupturable member such that after the secondary sleeve  
25 has been located in the apparatus to close the at least  
26 one fluid port, the rupturable member may be ruptured  
27 by fluid pressure within the throughbore to permit flow  
28 of fluid through the throughbore in the apparatus. In  
29 this example, the secondary sleeve may include a  
30 releasable locking mechanism to releasably lock the  
31 secondary sleeve to the apparatus.

32  
33 Examples of apparatus for circulating fluid in a  
34 borehole in accordance with the invention will now be  
35 described with reference to the accompanying drawings,  
36 in which:-

1        Fig. 1 is a cross-sectional view through one half  
2        of a first example of apparatus for circulating  
3        fluid in a borehole;

4        Fig. 2 is a schematic diagram showing an indexing  
5        slot and support surfaces of the apparatus shown  
6        in Fig. 1; and

7        Fig. 3 is a cross-sectional view through one half  
8        of a second example of apparatus for circulating  
9        fluid in a borehole.

10

11       Fig. 1 shows apparatus 1 for circulating fluid in a  
12       borehole. The apparatus 1 comprises an outer body  
13       member 2 having a jet port 3 and an exhaust port 4.  
14       Mounted within the body member 2 is a seal housing 5 to  
15       which is connected a travel pin mounting member 6 in  
16       which a travel pin 7 is mounted. Above the travel pin  
17       mounting 6 are two thrust bearings 8 between which a  
18       return spring 9 is located. The exhaust port 4  
19       communicates between the outside of the body member 2  
20       and void 10 in which the return spring 9 is located.  
21       Mounted on the upper thrust bearing 8 is a piston ring  
22       11 to which a piston sleeve 12 is threadedly mounted.  
23       The piston sleeve 12 extends past the void 10, pin  
24       mounting member 6 and terminates adjacent to the seal  
25       housing 5. In the piston sleeve 12, adjacent the seal  
26       housing 5 is a piston sleeve port 13. The void 10 is  
27       isolated from the central throughbore 14 of the  
28       apparatus by seals 15, 16. Hence, the void 10 is only  
29       exposed to pressure externally of the body member 2.  
30       Therefore, the combination of the piston ring 11 and  
31       piston sleeve 12 acts as a differential piston  
32       operating on the pressure differential between the  
33       throughbore 14 and the outside of the body member 2.  
34       In the outside surface of the piston sleeve 12 is an  
35       indexing slot 17 which co-operates with travel pin 7 to  
36       form an indexing mechanism. In addition, support

1 surface 18 on the seal housing 5 co-operates with a  
2 support surface 19 on the piston sleeve 12 such that  
3 loads between the piston sleeve 12 and body piece 2 are  
4 not borne solely by the travel pin 7 and slot 17 but  
5 are borne primarily by the support surfaces 18, 19.  
6 This has the advantage of reducing fatigue of the  
7 travel pin 7.

8  
9 The indexing slot 17 and support surfaces 18, 19 are  
10 shown in more detail in Fig. 2. The indexing slot 17  
11 comprises: three closed positions 17a in which the  
12 sleeve 12 obturates the fluid port 3 when the travel  
13 pin is in the position 17a; an open position 17b in  
14 which, when the pin moves to the position 17b, the  
15 piston sleeve port 13 aligns with the fluid port 3 to  
16 permit fluid communication from the throughbore 14 to  
17 outside the apparatus 1 through the ports 3, 13; and,  
18 four rest positions 17c which correspond to the  
19 position occupied by the travel pin 7 when there is no  
20 fluid flow or pressure in the throughbore 14. The slot  
21 17 is continuous around the outside of the piston  
22 sleeve 12.

23  
24 Although not shown in detail in Fig. 2, the slot 17 is  
25 configured to permit movement of pin 7 relative to the  
26 slot 17 in only one circumferential direction to  
27 prevent the pin 7 reversing to a previous position.  
28 The geometrical configuration of the slot 17 would be  
29 well known and obvious to a person skilled in the art.

30  
31 It can be seen from Fig. 2 that the support surfaces  
32 18, 19 are configured such that when travel pin 7 is in  
33 one of the positions 17a, surface portions 19a of the  
34 piston support surface 19 abut against surface portions  
35 18a of the seal housing support surface 18. When the  
36 travel pin 7 is located in the position 17b in the

1 indexing slot 17, surface portions 19a in the piston  
2 support surface 19 abut against surface portions 18b on  
3 the seal housing support surface 18 and surface  
4 portions 18a on the seal housing support surface 18  
5 abut against surface portions 19b on the piston support  
6 surface 19. The indexing slot 17 and the support  
7 surfaces 18, 19 are configured such that when the  
8 travel pin 7 is located in position 17a or 17b, the  
9 primary loading between the sleeve 12 and seal housing  
10 5 is borne by the support surfaces 18, 19 rather than  
11 the travel pin 7.

12

13 In use, the apparatus 1 is coupled into a portion of  
14 drillstring and lowered into a borehole with the sleeve  
15 12 in the position shown in Fig. 1.

16

17 When fluid, such as drilling fluid or mud is pumped  
18 through the drillstring, the fluid will flow through  
19 the throughbore 14 in the apparatus 1 and the pressure  
20 differential between the throughbore 14 and the annulus  
21 between the outside of the body member 2 and the inside  
22 surfaces of the borehole will cause the piston 12 to  
23 move downwards and the travel pin 7 to move to position  
24 17a. Each time pumping of the fluid into the  
25 drillstring is stopped, the differential pressure will  
26 be relaxed from the piston 12 and the travel pin 7 will  
27 return to the rest position 17c. When it is desired to  
28 circulate fluid out of the apparatus 1 through the jet  
29 port 3, the drilling fluid is stopped and restarted  
30 repeatedly until the travel pin 7 moves to position 17b  
31 in the indexing slot 17. When the travel pin 7 moves  
32 to position 17b, the port 13 in the piston sleeve 12  
33 aligns with the jet port 3 to permit fluid to pass into  
34 the annulus between the outside surface of the body  
35 member 2 and the inside surface of the borehole through  
36 ports 3, 13. This permits all of, or a proportion of,

1 the drilling fluid to be circulated to the surface  
2 without passing through the drillbit at the end of the  
3 drillstring, and facilitates flushing out of any drill  
4 cuttings located in the borehole above the position of  
5 the jet ports 3.

6  
7 It is possible that nozzles may be incorporated into  
8 the ports 3 to facilitate only a proportion of the  
9 drilling fluid to exit the apparatus through the ports  
10 3. This feature would have the advantage of permitting  
11 the remaining proportion of the fluid to pass down  
12 through the BHA and out of the drill bit. This may be  
13 particularly advantageous during certain drilling  
14 operations, such as coring. The nozzles may be  
15 removable or replaceable and may be available in a  
16 number of orifice sizes. This would permit an operator  
17 of the apparatus to choose the proportion of fluid that  
18 is diverted out of the apparatus 1 through the jet  
19 ports 3.

20  
21 Fig. 3 shows apparatus 20 for circulating fluid in a  
22 borehole. The apparatus 20 is similar to the apparatus  
23 1 shown in Fig. 1, except that the apparatus 20 has a  
24 secondary inner sleeve 21 located within the piston  
25 sleeve 12 and the secondary sleeve 21 is secured to the  
26 sleeve 12 by a shear pin 22. In addition, the  
27 secondary sleeve 21 has a port 23 in its side wall  
28 which is aligned with fluid port 13 in the piston  
29 sleeve, when the secondary sleeve 21 is secured to the  
30 piston sleeve 12 by the shear pin 22.

31  
32 In normal operation, the apparatus 20 operates  
33 identically to the apparatus 1 shown in Fig. 1.

34  
35 However, in the event that for some reason it is not  
36 possible to return the piston sleeve 12 from the open

1 position to the closed position (ie. return the travel  
2 pin from position 17b to position 17a) then an  
3 extrudable spherical ball may be dropped down the  
4 drillstring into the apparatus 20. Typically, the  
5 extrudable ball may be manufactured from a plastic, an  
6 elastomeric or a rubber material. When the ball is  
7 dropped into the piston sleeve 12, it rests on upper  
8 shoulder 25 of the secondary sleeve 21. In this  
9 position fluid flow from the throughbore 14 out of the  
10 jet ports 3 is prevented by the ball. When the fluid  
11 pressure above the ball is increased, this causes shear  
12 pin 22 to shear and the secondary sleeve 21 moves  
13 downwards relative to the piston sleeve 12 until  
14 shoulders 26, 27 abut against each other. In this  
15 position, the port 23 is clear of the bottom end of the  
16 piston sleeve 12 and further pressure above the  
17 extrudable ball causes the ball to move down within the  
18 secondary sleeve 21 until it butts against a lower  
19 shoulder 24 in the piston sleeve 21. In this position  
20 fluid is permitted to flow from the throughbore into  
21 the piston sleeve 21 and exit from the piston sleeve 21  
22 via the ports 23.

23  
24 Hence, the apparatus 20 permits drilling operations to  
25 be continued even if it is not possible to return the  
26 piston sleeve 12 from the open to the closed position  
27 and permits drilling operations to be continued without  
28 requiring retrieval of the drillstring to the surface  
29 in order to correct the problem.

30  
31 As an alternative to the sleeve 21 it would be possible  
32 to use a sleeve with no ports 23 and a burst disc  
33 located at one end. This sleeve could be dropped into  
34 drillstring from the surface in the event that it is  
35 not possible to return the sleeve 12 from the open to  
36 the closed position. The sleeve with the burst disc

1 would then obturate the port 13 when it fell into  
2 position within the piston sleeve 12. The burst disc  
3 may then be burst by increasing fluid pressure in the  
4 throughbore 14 to permit fluid to flow through the  
5 sleeve and permit normal drilling operations to  
6 continue.

7  
8 Advantages of the invention are that it permits  
9 circulation of fluid in a borehole without requiring  
10 the fluid to pass through the drill bit and provides an  
11 indexing mechanism to permit repeated operation of the  
12 tool to facilitate circulation of fluid through the  
13 side walls of the tool or alternatively to close the  
14 tool and continue drilling operations.

15  
16 In addition, the invention may also be used in well  
17 control situations as it would be possible to use the  
18 apparatus to introduce heavy mud above an influx of gas  
19 and/or oil to control the influx.

20  
21 A further advantage is that the apparatus shown in  
22 Figs. 1 and 3 uses differential pressure between the  
23 throughbore 14 of the apparatus 1, 20 and the external  
24 pressure outside the apparatus in order to move the  
25 piston sleeve 12 from the closed to the open positions  
26 and from the open to closed positions. In addition,  
27 the use of an indexing mechanism permits the sleeve to  
28 be retained in the closed or open position irrespective  
29 of the flow rate of fluid through the throughbore 14,  
30 provided that the pressure in the throughbore is  
31 greater than the pressure externally off the tool.

32  
33 Modifications and improvements may be incorporated  
34 without departing from the scope of the invention.

35

1    CLAIMS

2  
3    1.   Apparatus for circulating fluid in a borehole  
4    comprising a body member adapted to form a portion of a  
5    length of drillstring, the body member having a  
6    throughbore therein, and a fluid port extending through  
7    a side wall of the body member; an inner sleeve movably  
8    mounted within the body member for movement between a  
9    closed position in which the inner sleeve obturates the  
10   fluid port and an open position in which the fluid port  
11   is permitted to communicate with the throughbore; a  
12   pressure differential means to generate a pressure  
13   differential across the inner sleeve to move the sleeve  
14   from the closed to the open position in use; and, an  
15   indexing mechanism which couples the inner sleeve to  
16   the body member to permit the inner sleeve to be  
17   selectively moved between the closed position and the  
18   open position and to maintain the inner sleeve in the  
19   closed or open position.

20  
21   2.   Apparatus according to claim 1, wherein the  
22   pressure differential means is provided by the inner  
23   sleeve which is in the form of a differential pressure  
24   piston.

25  
26   3.   Apparatus according to claim 2, wherein the  
27   pressure differential means also comprises sealing  
28   means to isolate a surface area of the piston exposed  
29   to pressure from outside the body member from a surface  
30   area of the piston exposed to fluid pressure in the  
31   throughbore.

32  
33   4.   Apparatus according to claim 1, wherein the  
34   pressure differential means comprises a restriction in  
35   the throughbore.

36



- 1     5.    Apparatus according to any of the preceding  
2     claims, wherein the inner sleeve obturates the fluid  
3     port in the closed position and another fluid port  
4     through the inner sleeve aligns with the fluid port in  
5     the body member when the inner sleeve is in the open  
6     position.  
7
- 8     6.    Apparatus according to claim 5, wherein a number  
9     of fluid ports are located circumferentially around the  
10    body member and the inner sleeve.  
11
- 12    7.    Apparatus according to any of the preceding  
13    claims, wherein the indexing mechanism includes a  
14    number of sequential indexing positions.  
15
- 16    8.    Apparatus according to claim 7, wherein there are  
17    a number of indexing positions in which the inner  
18    sleeve is in the closed position and one indexing  
19    position in which the sleeve is in the open position.  
20
- 21    9.    Apparatus according to claim 7 or claim 8, wherein  
22    the indexing mechanism comprises a slot or groove  
23    formed on the outside surface of the inner sleeve which  
24    cooperates with a pin mounted on the body member.  
25
- 26    10.   Apparatus according to any of the preceding  
27    claims, wherein the fluid port includes a restriction.  
28
- 29    11.   Apparatus according to claim 10, wherein the  
30    restriction is removable or replaceable.  
31
- 32    12.   Apparatus according to any of the preceding  
33    claims, wherein the inner sleeve moves in a direction  
34    parallel to a longitudinal axis of the throughbore and  
35    rotates relative to the body member during movement  
36    from the closed position to the open position.

1 13. Apparatus according to any of the preceding  
2 claims, wherein the apparatus further comprises a  
3 secondary inner sleeve movably mounted within the inner  
4 sleeve, the second inner sleeve being moveable relative  
5 to the inner sleeve to close the fluid port when the  
6 inner sleeve is in the open position.

7  
8 14. Apparatus according to claim 13, wherein the  
9 secondary sleeve is moved to close the fluid port by  
10 dropping a member from the surface of the borehole into  
11 the throughbore so that the member engages with the  
12 secondary inner sleeve.

13  
14 15. Apparatus according to claim 13, wherein the  
15 secondary sleeve is inserted into the apparatus from  
16 the surface of the borehole through the drillstring,  
17 during use of the apparatus.

18  
19 16. Apparatus according to claim 15, wherein the  
20 secondary sleeve includes a rupturable member such that  
21 the secondary sleeve may be pumped by fluid pressure  
22 into position in the apparatus to close the fluid port  
23 and excess fluid pressure above the member ruptures the  
24 rupturable member to permit fluid flow through  
25 throughbore in the apparatus.

26  
27 17. Apparatus according to claim 15 or claim 16,  
28 wherein the secondary sleeve includes a releasable  
29 locking mechanism to lock the secondary sleeve to the  
30 apparatus when the secondary sleeve closes the fluid  
31 port.

32  
33 18. Apparatus substantially as hereinbefore described  
34 with reference to the accompanying drawings.



Application No: GB 9701599.4  
Claims searched: 1 to 18

Examiner: David Harrison  
Date of search: 13 February 1997

**Patents Act 1977**  
**Search Report under Section 17**

**Databases searched:**

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): EIF (FGL, FLP)

Int Cl (Ed.6): E21B

Other:

**Documents considered to be relevant:**

Category	Identity of document and relevant passage	Relevant to claims
X,E	GB 2302895 A (Phoenix P.A. Ltd.) 5 February 1997; Whole document	1-7,9,12
X	GB 2006853 A (Halliburton Company) Whole document	1-3,5-9
X	EP 0223552 A2 ✓ (Halliburton Company) Whole document	1-3,5-9
X	EP 0063519 A2 ✓ (Schlumberger Technology Corporation) Whole document	1-3,5-9
X	US 4298077 (Emery) Whole document.	1-7,9,12

X Document indicating lack of novelty or inventive step  
Y Document indicating lack of inventive step if combined with one or more other documents of same category.

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A Document indicating technological background and/or state of the art.  
P Document published on or after the declared priority date but before the filing date of this invention.  
E Patent document published on or after, but with priority date earlier than, the filing date of this application.